



Electricity

INTRODUCTION

We are surrounded by technology and innovation. Electricity is one of the greatest innovations of mankind. It has now become a part of our daily life and one cannot think of a world without electricity. Almost all the devices at home, businesses and industries are running because of electricity (Fig. 1.1). The primary use of electricity depends on the place where it is used and the nature of the facility. You must have seen bulbs, tubelights, refrigerators, TVs and other electronic gadgets at your home and you must have also felt cool because of a rotating fan at your home. All this is possible due to electricity. Electricity plays a vital role in our day-to-day life and it also plays a vital role in the country's economy.

The country's development is measured in terms of per person consumption of electricity. At present everything in human life is dependent on electricity whether it is in the health, transport, agriculture or industrial sector.

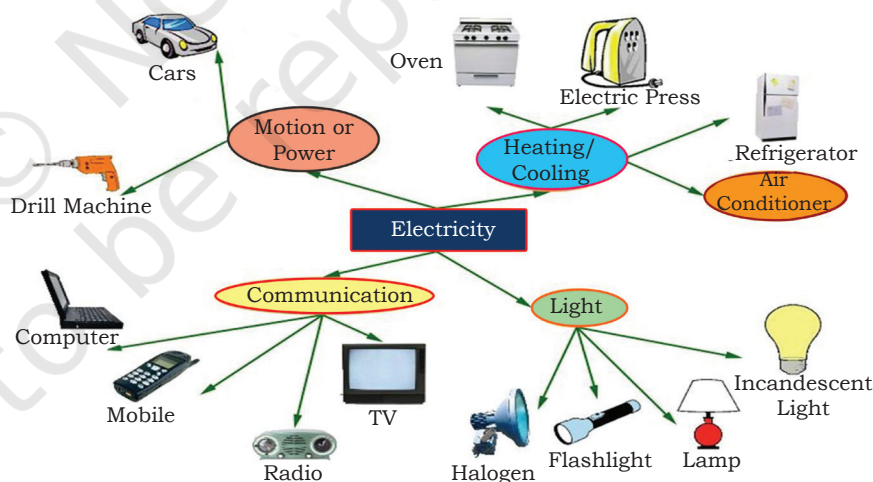


Fig. 1.1 Use of Electricity

SESSION 1: ELECTRICITY GENERATION CONCEPT

Origin of Electricity

Electricity is one of the most commonly used forms of energy. The word electricity comes from Greek word *elektron* which means amber. It is converted from mechanical (turbine) to electrical energy (generator). Many people give credit to Benjamin Franklin for discovering electricity, but his experiments only helped to establish the connection between lightning and electricity.

Basic Concept of Electricity

Electricity is a type of energy which involves the flow of electrons. All elements are made up of atoms. The centre of an atom is called nucleus. The nucleus has positively charged particles known as protons and electrically neutral particles called neutrons. The nucleus of an atom is surrounded by negatively charged particles known as electrons (Fig. 1.2). The negative charge of an electron is the same as the positive charge of a proton, and the number of electrons in an atom is equal to the number of protons.

Distribution of Electrons in the Orbits of Copper Atom (Good Conductor of Electricity)

From the generating station, electricity arrives at homes through wires. Electric lamps, electric heaters, fans, computers, etc., use electricity to work. Many appliances, such as washing machines and electric cookers use electricity. In factories, electricity is used to run machines. People who deal with electricity and electrical devices are called electricians.

There are two types of electric charges — positive and negative charges. Similar charges repel each other and opposite charges attract. This means that if you put two negative charges close together, they will move apart. This is also true for two positive charges. But if you put a positive charge and a negative charge close together, they will attract each other.

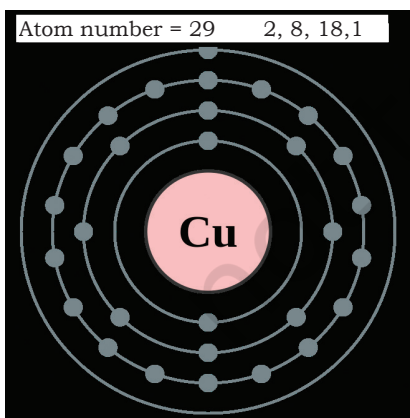
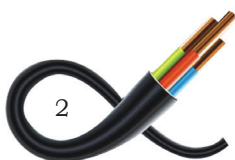


Fig. 1.2 Electrons



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Importance of Electricity

Electricity makes it possible to light our homes, roads, offices, markets and factories. This helps us to continue work during night hours. A power station provides us electricity. If the supply of electricity fails, electrical torches are used for providing light. We use electricity to operate the pump that lifts water from wells or ground level to roof-top water tank. Other electrical equipment like AC, geyser, electrical iron, television, refrigerator, induction cooker, oven, etc., also require electricity to run (Figs. 1.3, 1.4 and 1.5).



Fig. 1.3 Electricity used for Lighting

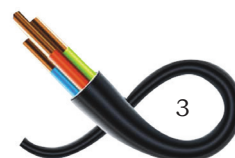


Fig. 1.4 Electricity used for Heating



Fig. 1.5 Electricity Pump

ELECTRICITY



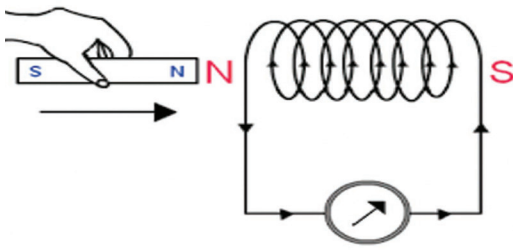


Fig. 1.6 Experiment of Michael Faraday

Generation of Electricity

The basic principle of electrical generator is Faraday's Law of Electromagnetic Induction (Fig. 1.6). An electrical generator (Fig. 1.7) is used to convert mechanical energy into electrical energy. Generation of electrical energy is just conversion of kinetic energy into electrical energy.

Experiment of Michael Faraday

Electromagnetic induction is the production of an electromotive force across a conductor, when it is exposed to a varying magnetic field. It is described by Faraday's Law of Electromagnetic Induction.

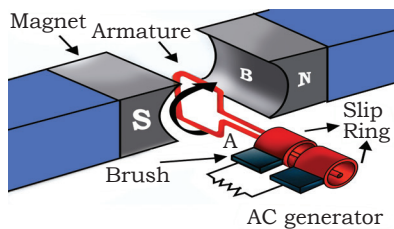


Fig. 1.7 Diagram of D.C. Generator

Electricity Generated by Electrochemical Cell

An electrochemical cell is a device which is capable of generating electrical energy through chemical reactions. A common example of an electrochemical cell (Fig. 1.8) is a standard 1.5 V cell meant for consumer use.



Fig. 1.8 Electrochemical Battery

Electricity Generated by Solar Cell

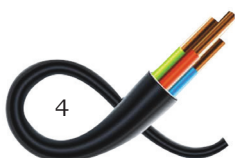
A solar cell (Fig. 1.9) is a device that converts light energy into electrical energy. This conversion is called the photovoltaic effect. Solar cells have many applications. They are used in situations where electrical power is unavailable, such as in remote areas, earth-orbiting satellites and space probes, consumer systems like handheld calculators or wrist watches.



Fig. 1.9 Electricity Generated by a Solar Panel made of Several Solar Cells

Electricity Generated by Thermal Power Station

A thermal power station (Fig. 1.10) is a power station in which heat energy is converted to electrical energy. In most parts of the world, the turbine is steam-driven. Water is heated, which then turns into steam and spins the



steam turbine which drives the electrical generator. In a thermal power station fuel, such as coal, oil or gas, is burned in a furnace to convert chemical to heat energy. This heat is used to change water into steam in the boiler and this drives the generator to produce electricity—mechanical to electrical energy.

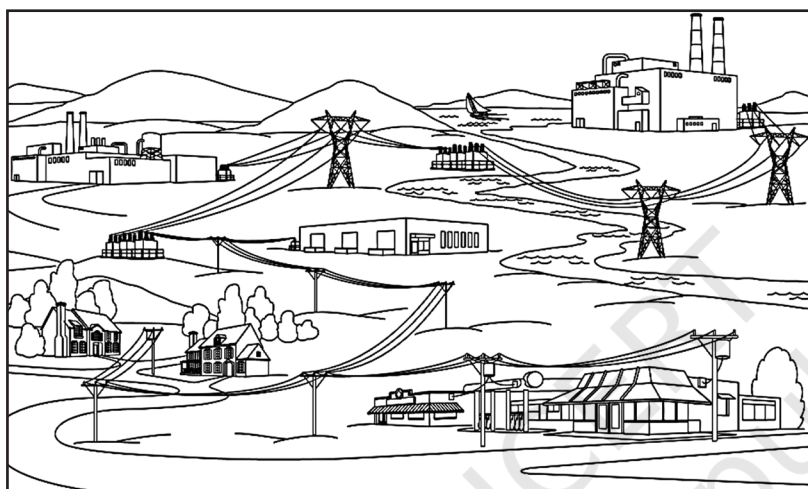
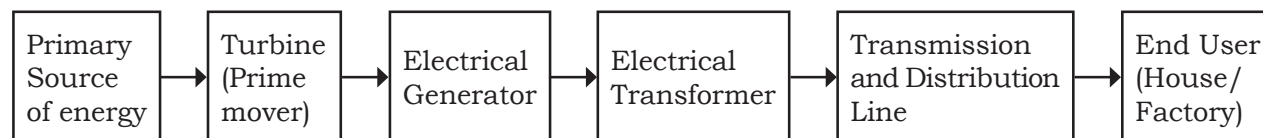


Fig. 1.10 Thermal Power Plant

Status of Electricity Production in India

1. Total Installed Capacity (as on 30.06.2017)

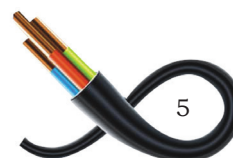
Fuel	MW	% of Total
Total Thermal	2,20,576	67.0%
Coal	1,94,553	59.1%
Gas	25,185	7.6%
Oil	838	0.3%
Hydro	44,614	13.6%
Nuclear	6,780	2.1%
Renewable Energy Sources*	57,260	17.4%
Total	3,29,231	100%

Source: Central Electricity Authority (CEA)

* Installed capacity, in respect, Renewable Energy Sources as on 31.03.2017.

Renewable Energy Sources include Small Hydro Project, Biomass Gasified, Biomass Power, Urban and Industrial Waste Power, Solar and Wind Energy

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Practical Exercise

Activity 1

Making an electrical quiz board for listing sources of electricity and their sharing percentage (%) in India

Objective

Students will be able to

1. identify the sources of electrical energy in India,
2. define their sharing percentage (%) and
3. make basic circuit connection.

Material required

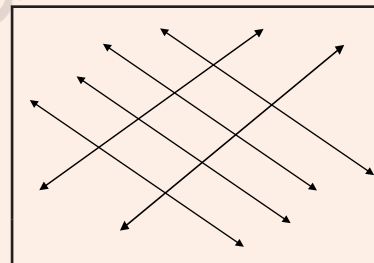
One cardboard (45cm × 15cm), insulated copper wire, one 9-volt bulb with holder, one 9-volt battery, 10 nos, connectors with socket

Tools and Equipment

S.No.	Particular	Specification	Quantity
1.	Screw Driver	6"	01
2.	Combination Plier	6"	01
3.	Wire Stripper	--	01
4.	Phase Tester	--	01

Coal	13.6
Gas	17.4
Oil	59.1
Hydro	7.6
Nuclear	0.3
Renewable	2.1

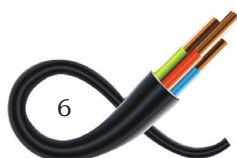
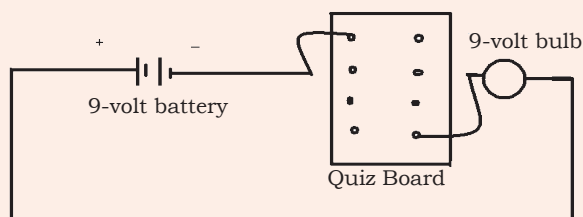
Front view of cardboard



Back view of cardboard

Fig. 1 Electrical Cardboard

Electrical Circuit Diagram of Electrical Quiz Board



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Procedure

1. Take one cardboard (45cm × 15cm) and fix pieces of insulated wire with two metal connectors at the end of each wire.
2. Paste the name of energy source and percentage as shown in the figure.
3. Connect each question to the correct answer by a wire at the back of the cardboard.
4. Connect 9-volt battery and 9-volt bulb as shown in the figure.
5. Clip one lead of connector to a question and clip the other lead to what you think is the correct answer.
6. If the answer selected by you is correct the bulb will glow because the connection wire on the back side of the cardboard will complete the circuit.
7. If the answer is wrong, the bulb will not glow.

Precautions

1. All the connections should be correctly fastened.
2. No wire should be left naked.
3. 'Questions' and 'Answers' should be connected correctly at the back side of the cardboard.

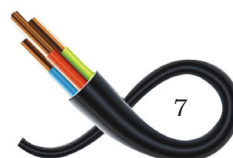
Check Your Progress

A. Fill in the Blanks

1. Electricity is a form of _____.
2. In a generator _____ energy is converted to electrical energy.
3. Electricity is also generated by _____ and _____ energy other than thermal energy.
4. The commonly used machine for generating electricity is called _____.
5. Law of electromagnetic induction was discovered by _____.

B. Match the Columns

- | | |
|------------------------|---------------|
| 1. Thermal Power Plant | (a) Renewable |
| 2. Wind Power Plant | (b) Coal |
| 3. Nuclear Power Plant | (c) Water |
| 4. Hydro Power Plant | (d) Uranium |



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C. Multiple Choice Questions

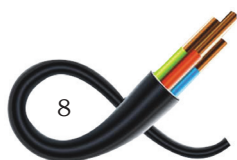
- Electricity was discovered by _____.
 - Isaac Newton
 - Benjamin Franklin
 - Max Plank
 - D. Rutherford
- Most of the electricity generated in India is by using _____.
 - wind
 - coal
 - solar
 - hydro
- Which of the following forms of energy is converted by a solar cell into electrical energy?
 - Wind
 - Thermal
 - Nuclear
 - Light
- Electricity is a type of energy which involves the flow of _____.
 - protons
 - neutrons
 - electrons
 - atoms
- If you put two negative charges close together, they will _____.
 - attract
 - repel
 - not interact
 - attract some time and repel some time

SESSION 2: BASIC UNITS AND EFFECTS OF ELECTRIC CURRENT

Electricity is a form of energy which though cannot be seen, but its effects can still be felt (Fig. 1.11).



Fig. 1.11: Electricity as form energy



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Various Effects of Electric Current

(a) Heating effect: Heat is produced in a conductor, like nichrome, due to the flow of current through it. It is called the heating effect of electric current or Joule's law of heating. When electricity flows through a conductor like tungsten, light is emitted (Fig. 1.12) from the surface of conductor due to heating, such as in an electric bulb.

(b) Chemical effect: When current is passed through an electrolyte, it breaks up in its ions. This is known as chemical effect of electric current.

(c) Magnetic effect: It was discovered by Faraday. A magnetic field (Fig. 1.13) is produced around the conductor through which the current flows. This is called the magnetic effect of electric current.

(d) Physical effect: When electricity flows through the human body, contraction of nerves takes place, which may be dangerous for a person's life. This is the physical effect of electric current.



Fig. 1.12 Heating effect of electric current

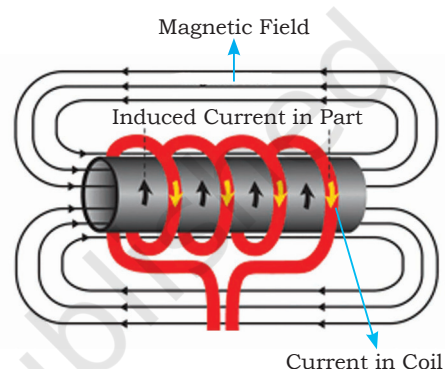


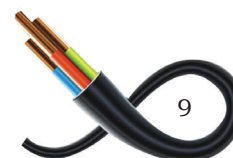
Fig. 1.14 Magnetic effect of electric current

Voltage, Current, Resistance, Capacitance and Inductance

If we place two objects, charged to different potential, side by side, charges will not move from one to the other. Now, if the two are connected using a conductor the flow of charges will take place. The charge will flow as long as there is a difference of potential between the two objects. The flow will stop as soon as their potential becomes equal. This flow of electric charge is called electric current.

The potential difference (PD) between two points is one volt when the work done in moving one coulomb of charge between these points is one joule.

Air current (air flow) and water current (water flow) can be easily understood. The flowing water in rivers constitutes water current. Similarly, if electric charge flows through a conductor it means there is an electric current in the conductor. In a torch, the cells provide



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necessary potential difference for the flow of charges or an electric current through the torch bulb to glow. It can also be observed that the torch gives light only when its switch is on. A continuous and closed path of an electric current is called electric circuit. Now, if the circuit is broken anywhere the current stops flowing. Electric current is expressed by the amount of charge flowing through a particular area in unit time. In other words, it is the rate of flow of electric charges.

Let us understand water flow and current. Water will not flow by itself in a perfectly horizontal tube. If one end of the tube is connected to a tank of water kept at a higher level, such that there is a pressure difference between the two ends of the tube, water will flow out of the other end of the tube. For the flow of charges in a conducting wire, the voltage plays an important role. The electrons move only if there is a difference of electric pressure called the potential difference or voltage. This difference of potential may be produced by a cell or a battery, consisting more than one electric cell. The chemical action within a cell generates the potential difference across the terminals of the cell. When the cell is connected to a conducting circuit element, the charge flows from one end to another.

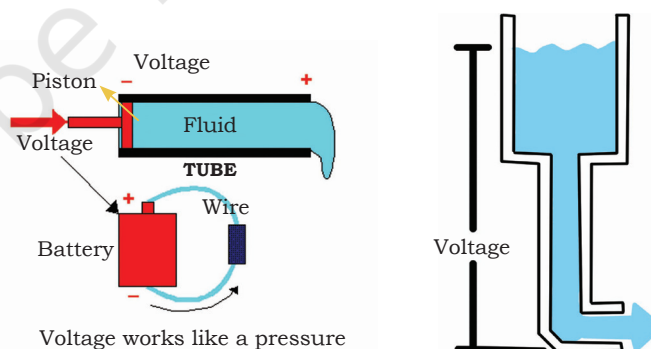
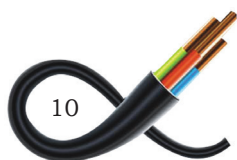


Fig. 1.14 Voltage

(a) Voltage

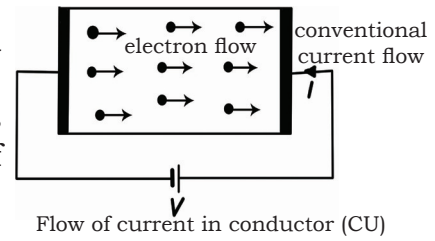
What makes the electric charge flow? It is voltage (Fig. 1.14). It refers to the pressure or tendency to drive the electrons in a circuit. Its unit is volt.



(b) Current

Flow of electrons in any conductor is called current (Fig. 1.15).

If electrons flow through a conducting wire, it is said that there is an electric current in the wire. Unit of current is ampere.



Electric current in the external circuit is directed from the positive to the negative terminal

Fig. 1.15 Flow of current in conductor

(c) Resistance

It is the property of a conductor to resist the flow of charge through it. The ratio of the voltage and current is called electric resistance of the conductor. Unit of resistance is Ohm (Ω) 1 ohm = 1 volt/1 ampere.

(d) Capacitance

Capacitance is the capability of a device for storing electric charge. Capacitance is expressed as the ratio of stored charge in coulombs to the impressed potential difference in volts. Its unit is farad.

In an electric circuit the device which stores charge is called capacitor (Fig 1.16). The ratio of the charge Q on one of the plates of a capacitor and the potential difference V between the plates is the capacitance, that is, $Q/V=C$.

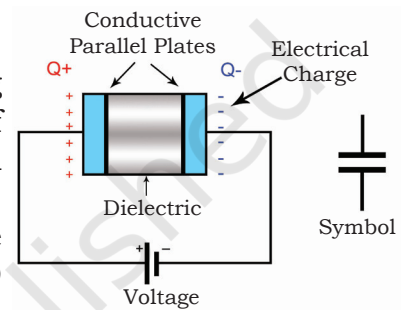


Fig. 1.16 Circuit diagram of a capacitor

(e) Inductance

If a changing magnetic field (flux) is linked with a coil of a conductor there is an electromotive force induced in it. The property of the coil of inducing electromotive force due to the changing flux linked with it is known as inductance (Fig. 1.17) of the coil. Due to this property an electrical coil is referred as inductor. An inductor can be defined as an energy storage device which stores energy in the form of magnetic field. Unit of inductance is henry.

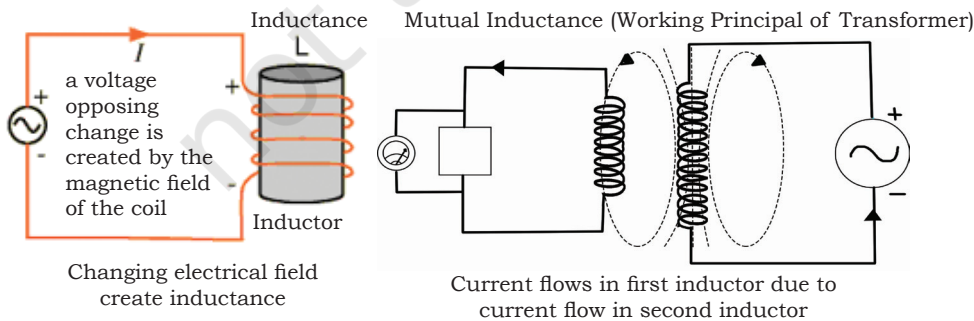
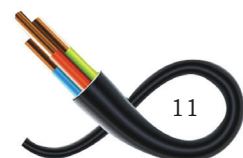


Fig. 1.17 Inductance



Understanding Series and Parallel Circuits

Series Circuit

If two or more resistors (loads) are connected in such a way that they form a chain, one after the other, then each carries the same current when the combination is connected with the supply source. They are said to be connected in series (Fig.1.18).

This circuit is called a series circuit.

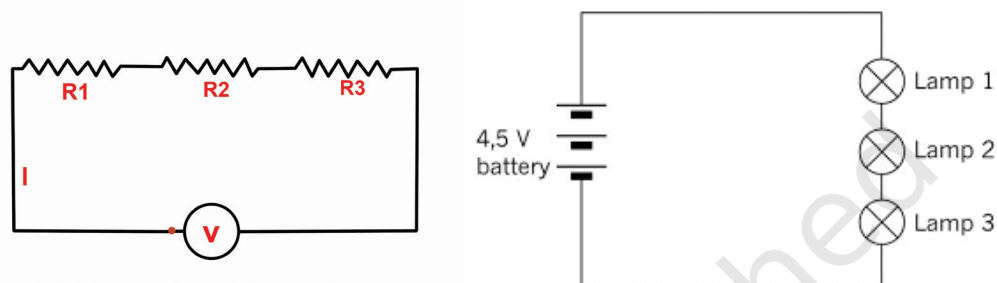


Fig. 1.18 Series circuit

In-series Circuit

Resultant Resistance

$$R = R_1 + R_2 + R_3$$

Parallel Circuit

When two or more resistors (loads) are connected in such a way that each forms a separate path and carries a part of total current, they are said to be arranged in parallel and the circuit is called parallel circuit (Fig. 1.19).

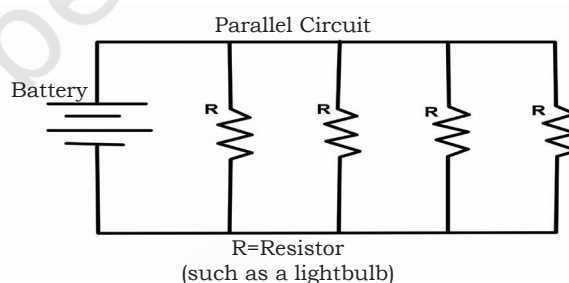
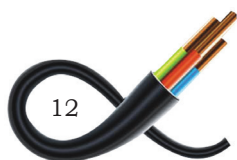


Fig. 1.19 Parallel circuit

In Parallel Circuit

Resultant Resistance

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}$$



(i) Ohm's Law

In any electrical circuit when physical conditions (temperature diameter and length) of a conductor are constant, voltage is directly proportional to the current (Fig. 1.20).

Mathematically: $V \propto I$

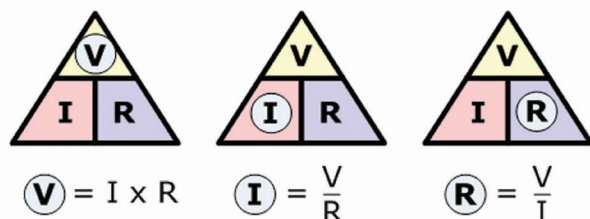


Fig. 1.20 Diagram of Ohm's Law

(ii) Kirchhoff's Current Law

It states that the total current or charge entering a junction or node is exactly equal to the charge leaving the node, as no charge is lost within the node. In other words, the algebraic sum of all the currents entering and leaving a node must be equal to zero, (Fig. 1.21), that is, I (current entering in the node) + I (current leaving the node) = 0.

This idea by Kirchhoff is commonly known as the Conservation of Charge or Kirchhoff's Current Law (KCL)

Here, the three currents entering in the node, I_1 , I_2 , I_3 are all positive in value and the two currents leaving the node, I_4 and I_5 are negative in value.

This means we can also rewrite the equation as: $I_1 + I_2 + I_3 - I_4 - I_5 = 0$

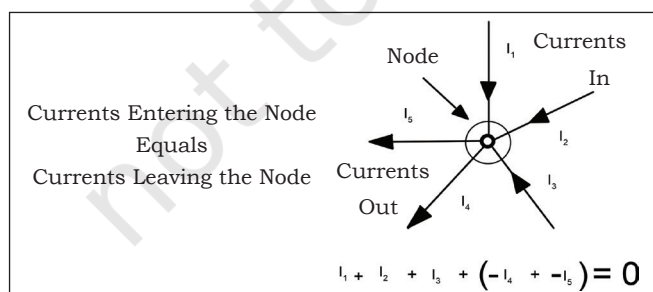
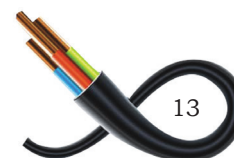


Fig. 1.21 Diagram of Kirchhoff's Current Law



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(iii) Kirchhoff's Voltage Law (KVL)

Kirchhoff's Voltage Law or KVL, states that in any closed-loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop. In other words the algebraic sum of all voltages within the loop must be equal to zero (Fig. 1.22). This is called Kirchhoff's Second Law or law of Conservation of Energy.

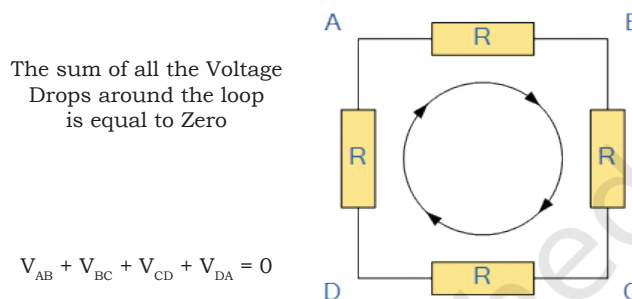
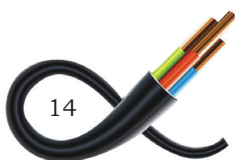


Fig. 1.22: Diagram of Kirchhoff's Second Law

Starting at any point in the loop continue in the same direction noting the direction of all the voltage drops, either positive or negative, and come back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or else the final voltage sum will not be equal to zero. Kirchhoff's voltage law can be used when analysing circuits.

When analysing either DC circuits or AC circuits using Kirchhoff's Circuit Laws, the following terminologies are used to describe the parts of the circuit being analysed:

- (a) **Nodes:** when any resistance is connected in the circuit the two terminals of resistance are called nodes.
- (b) **Loop:** when multiple resistances are connected and create a circle, it is called loop.
- (c) **Path:** when multiple resistances are connected with an electrical circuit, the direction of the current flow is called path.
- (d) **Meshes:** hundreds of resistances connected in a circuit in parallel and in series are called meshes.



Check Your Progress

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A. Fill in the Blanks

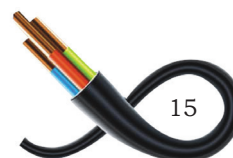
1. Light emitted from the surface of conductor is due to _____ of electric current.
2. The unit of current is _____.
3. The unit of resistance is _____.
4. The unit of capacitance is _____.
5. The unit of inductance is _____.

B. Match the Columns

- | | |
|--------------------|----------------------------------|
| 1. Voltage Storing | A. Charge |
| 2. Current | B. Obstruction in flow of charge |
| 3. Resistance | C. Flow of charge |
| 4. Capacitance | D. Pressure |

C. Multiple Choice Questions

1. Voltage is like _____.
(a) energy
(b) volume
(c) pressure
(d) temperature
2. If an electric circuit could be compared to a water circuit, then the current would be analogous to the _____.
(a) water
(b) water flow
(c) water pressure
(d) water pump
3. Kirchhoff's Current Law or KCL says that the algebraic sum of all currents leaving a node should be _____.
(a) one
(b) two
(c) three
(d) zero
4. In any electrical circuit when physical condition (temperature, diameter and length) of a conductor are constant, the voltage is directly proportional to _____.
(a) current
(b) resistance
(c) power
(d) energy
5. If two or more resistors (loads) are connected in such a way that they form a chain, it is called _____.
(a) parallel circuit
(b) series circuit
(c) closed circuit
(d) open circuit



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D. Short Answer Questions

1. Describe Ohm's Law.
2. What is electricity?
3. Write any one type of effect of electric current.
4. What is a parallel circuit? Explain with diagram.
5. What do you understand by the terms voltage, current and resistance?

SESSION 3: CONCEPT OF ELECTRICAL POWER AND ENERGY

Difference between Power and Energy

Power is the measurement of energy transfer by an electrical circuit in unit time. Electrical power and energy play a vital role in today's society. Electrical power and energy involve generation, transmission and distribution of electrical energy reliably and efficiently to meet consumer demands. Electrical appliances at home transfer energy from the mains to supply heat and light in our homes. Electric energy also operates appliances, such as TV, microwave, computers, etc. The units measured by an electricity meter and used to calculate the consumption (electricity bill), are called kilowatt hours. The cost of each unit of electricity varies. The electricity bill is calculated by working out the number of units used and multiplying it with the cost of per unit.

Electrical Power

It is the rate at which electrical energy is consumed by an electrical appliance. Unit of electrical power is watt.

1000 watt = 1 kilowatt

Electrical Power in DC and AC Circuit

Electrical Power in DC Circuit

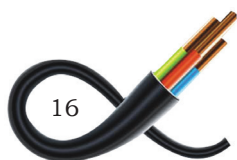
$$P = V \times I$$

$$P = I^2 R$$

$$P = V^2 / R$$

where V = voltage, I = current and R = resistance

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Electrical Power in AC Circuit

$$P = VI \cos \phi,$$

where $\cos \phi$ = power factor and P = power

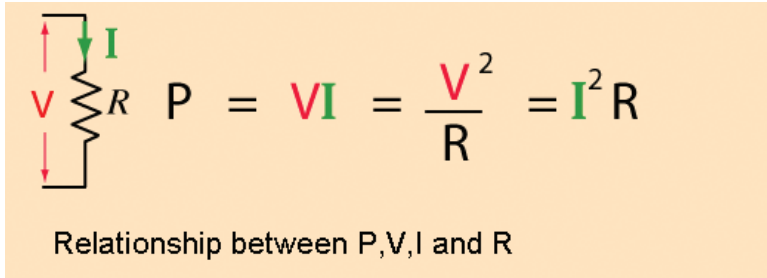


Fig. 1.23 Diagram shows relationship between P, V, I and R

Electrical Energy

Electrical energy is the capacity for doing electrical work.

Energy in watt hour is the multiplication of power in watt and time in hour. This is the basic unit of energy. The commercial unit of energy is kilowatt-hour (Fig. 1.24).

Electrical Energy = power $\times$ time

Electrical Energy = watt $\times$ hour

Electrical Energy = 1000 watt $\times$ 1 hour

Electrical power in a circuit is the rate at which energy is used or generated within a circuit. A source of energy, such as a battery, will deliver power while the connected load uses it. Light bulbs and heaters are examples of usage of electrical power and its conversion into either heat, or light, or both. The higher the value or rating in watts, the more the electrical power they are likely to consume.

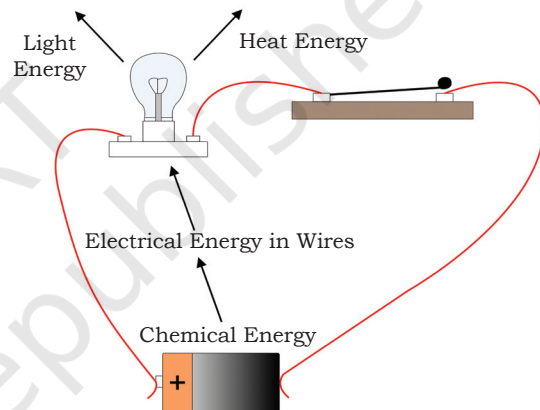


Fig. 1.24 Diagram shows conversion of chemical energy into electrical energy

Electric Power Calculation

Electrical power (Fig. 1.25) is also expressed as the rate by which energy is transferred in the circuit. If one joule of work is either absorbed or delivered at a constant rate of one second, then the corresponding power will be one watt. So power can be defined as '1Joule/sec = 1Watt'. Then we can say that one watt is equal to one joule per second and electrical power can be defined as the rate of doing work or the rate of transferring of electrical energy.

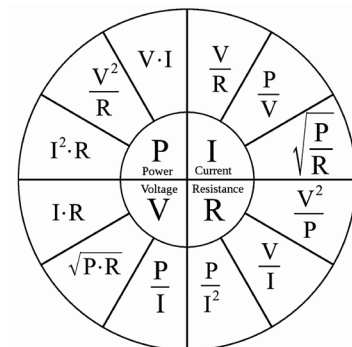
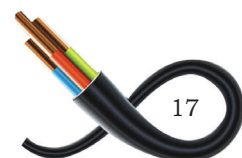


Fig. 1.25 Diagram shows electric power circulation

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Electrical Circuit Symbols			
Cell		Battery	
Lamp		AC Supply	
Switch		Ammeter	
Voltmeter		Galvanometer	
Resistor		Potentiometer	
Transformer		Heating Element	

Fig. 1.26 Electrical circuit symbols

Use of Voltmeters and Ammeters

(a) Voltmeters

- A voltmeter is always connected across the device or in parallel.
- A voltmeter has a very high internal resistance, so as to not draw a large current from the circuit.

(b) Ammeters

- An ammeter is always connected in series.
- An ammeter has a very low internal resistance, so as to not generate a drop in potential.

Power and Energy Calculation in DC and AC System

(a) Watts

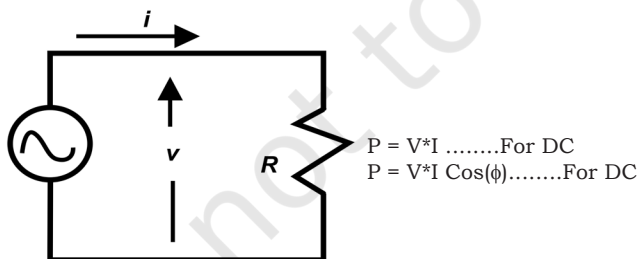


Fig. 1.27 Diagram of electric power measurement

This is a unit of power. It is the rate at which electricity is used at a specific moment (Fig. 1.27).

1 kilowatt = 1,000 watt,

1 megawatt = 10,00,000 watt.

Example: 9-watt LED light bulb consumes 9 watts of electricity at any moment when turned on.



(b) Watt-hour

One watt-hour is the energy consumed when one watt of power is used for one hour.

$$\text{watt} \times \text{hour} = \text{watt} \times \text{hour}$$

The commercial unit of energy is kilowatt-hour (kWh).

Example

09-watt LED bulb, which draws 09 watts at any one moment, uses 09 watt-hours of electricity within a span of one hour.

Here's the general rule for calculating power dissipation:

$$\text{Power: } P = V \times I$$

where V = voltage applied across the circuit and I = current flowing in the circuit

Example

We begin with one of the simplest circuits: A battery hooked up to a single resistor.

Here, we have a single 9V battery, and a single 100Ω (100 Ohm) resistor, hooked up with wires to form a complete circuit. Calculate power and energy in 10 hours (Figs A and B).

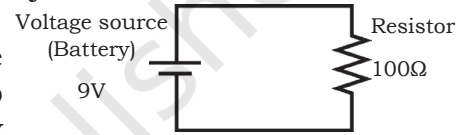


Fig. A

Calculation of Power

As per the formula of power in DC circuit

$$\text{Electrical Power} = \text{Voltage} \times \text{Current, i.e.,} \\ P = V \times I$$

As per Ohm's Law,

$$V = IR \text{ (where } R = \text{resistance of the circuit)} \\ I = V/R$$

$$\text{Then, } P = V \times V/R$$

$$P = V^2/R$$

$$P = 9^2/100 = 81/100 = 0.81 \text{ watt}$$

Solution: Power dissipated in the electrical circuit is 0.81 Watt.

Calculation of Electrical Energy

As per the formula of electrical energy in DC circuit

$$\text{Electrical energy} = \text{Power (in watt)} \times \text{Time (in hours)}$$

$$\text{Therefore, electrical energy consumed for 10 hours} \\ = 0.81 \times 10 = 8.1 \text{ watt-hours}$$

Solution: Energy consumed by the above electrical circuit is 8.1 Unit.

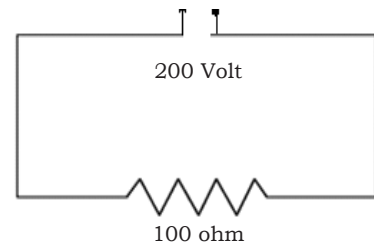
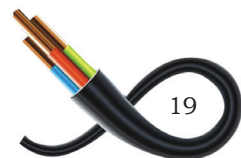


Fig. B



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Check Your Progress

A. Fill in the Blanks

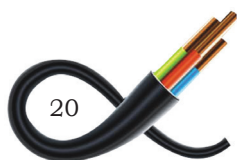
1. Ammeter is always connected in _____ in a circuit.
2. Voltmeter is always connected _____ across a circuit.
3. The unit of power is _____.
4. The unit of electrical energy is _____.
5. 1000 watt $\times$ 01 Hour Electrical Energy is called _____ energy.

B. Match the Columns

- | | |
|--------------------|---------------------------------------|
| 1. Battery | (a) Current indicating device |
| 2. Galvanometer | (b) Resists the flow of current |
| 3. Resistor | (c) A resistance which generates heat |
| 4. Heating element | (d) Combination of two or more cells |

C. Multiple Choice Questions

1. AC stands for _____.
(a) Alternating Current
(b) Accumulated Current
(c) Air Current
(d) None of the above
2. The internal resistance of an ammeter is _____.
(a) very high
(b) very low
(c) zero
(d) infinite
3. Rate of doing electrical work is called electric _____.
(a) energy
(b) current
(c) potential
(d) power
4. Potentiometer is an electric device that gives variable _____.
(a) power
(b) resistance
(c) voltage
(d) current
5. One commercial unit electrical energy is equal to _____.
(a) 1 watt $\times$ 1 hour
(b) 10 watt $\times$ 1 hour
(c) 100 watt $\times$ 1 hour
(d) 1000 watt $\times$ 1 hour



D. Short Answer Questions

1. What do you understand by the term electrical power?
2. What is electrical energy?
3. What do you mean by one commercial unit of electrical energy? Explain briefly.
4. An electric iron is connected across 220 volt power supply. If the resistance of the iron is 50 ohm, then calculate
 - (a) the current flowing through the iron.
 - (b) electrical power of the iron.
 - (c) energy used in commercial units (kWh) if the iron is connected for 2 hours.
5. One LED bulb is labeled 220 volt and 11 watt. If the bulb is connected to 220 volt power supply, then calculate
 - (a) the current flowing through the LED bulb.
 - (b) the amount of electrical energy used by the LED bulb in 08 hours.

E. Draw the Electrical Symbol of the following

1. Cell
2. Battery
3. Bulb
4. Resistance
5. Switch

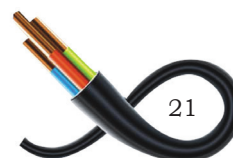
SESSION 4: IMPORTANCE OF EARTHING SYSTEM**Importance of Earthing and its Types**

Earthing system in an electrical circuit is for safety purpose. The earthing system provides an alternative path for high and dangerous current to flow to the earth so that the problem of electric shock and damage to equipments does not occur.

The metallic connection between electrical machines and devices with the earth plate, commonly known as earth electrode, through a thick wire of low resistance to provide safety is known as earthing.

Metallic parts of an equipment are earthed and if the equipment's insulation fails there will be dangerous current present on the surface of the equipment. This may cause a short circuit and the fuse will blow off immediately.

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Earthing

Earthing means connection of non-current carrying parts (metallic parts) of electrical apparatus to the earth to discharge electrical energy without any danger.

Earthing is done by connecting the appliance or machinery to earth by a good conductor known as earth electrode. Earthing is done to save human life from the danger of electrical shock, in case a human body comes in contact with a live wire.

If earthing is done correctly and the metallic part comes in contact with a live wire, it will be discharged in to the earth. In this condition, due to zero potential of earth a large amount of the current flows to the earth. If the current exceeds the limiting value of the fuse, it blows off or the MCB trips and cuts off the supply from appliance.

Different Terms used in Electrical Earthing

- (a) **Earthing:** The proper electrical contact between electrical installation and the earth is known as earthing.
- (b) **Earthed:** When an electrical machine, appliance or wiring is connected to the earth through earth electrode, it is known as earthed.
- (c) **Earth electrode:** A pipe or plate buried in the earth for discharge of electricity is known as earth electrode.
- (d) **Earthing lead:** The conducting wire or conductive strip connected between earth electrode and electrical installation and machine is called earthing lead.
- (e) **Earthing resistance:** This is the resistance between earth electrode and the earth in ohms.

Specification for Earthing

S.No.	Details	Specification
1.	Distance of earth from building	More than 1.5 meter from the building
2.	Size of earth electrode	Not be less then 2.9mm^2 or 14 SWG
3.	Resistance of earth	Not greater than 8 ohm

CONSUMER ENERGY METER TECHNICIAN — CLASS IX



The earth electrode and earth wire should be of the same material.

Points to be earthed

1. Earth pin of 3 pin and 5 pin plug and socket
2. All metal parts of the electrical machine, e.g., motor, heater geyser and mixer
3. Metallic frame of electrical machines
4. The neutral conductor of 3-phase 4-wire system
5. Pole, tower, armouring of cable
6. Stray wire of overhead lines

Importance of electrical earthing

Electrical earthing is important to

1. save human life from the danger of shock from leaking current.
2. maintain the line voltage constant.
3. protect large machines and buildings from atmosphere lighting.
4. avoid the risk of accident in an electrical sub-station and other installation.

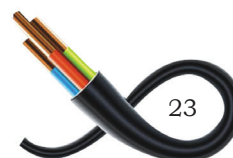
Earth resistance of different electrical installations

Large power station	0.5 Ohm
Major power station	1.0 Ohm
Small sub-station	2.0 Ohm
In-house wiring and such other case	5.0 to 8.0 Ohm

Types of Earthing

- (a) **Strip earthing:** In this type of earthing galvanised iron strip of 25mm × 4mm or copper strip of 25mm × 1.6mm are laid in horizontal trenches of minimum depth of 0.5 meter and covered with charcoal and salt.
- (b) **Rod earthing:** In this type of earthing system 12.5 mm diameter of solid rod of copper or 16 mm diameter of solid rod of galvanised iron are fitted vertically into the earth not less than 2.5 meter on earth surface.
- (c) **Pipe earthing:** It is cheaper and the best form of earthing. In this type of earthing a hollow pipe of 38 mm diameter and 2.5 meter

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long GI is placed underground and covered with charcoal and salt.

- (d) **Plate earthing:** In this type of earthing system, a plate of either copper with dimensions $60\text{cm} \times 60\text{cm} \times 3.18\text{mm}$ or galvanised iron (GI) of dimensions $60\text{cm} \times 60\text{cm} \times 6.35\text{mm}$ is buried vertical in the earth pit which should not be less than 3 metre from the surface of ground.

Atmospheric Lightning

Atmospheric lightning is a form of visible discharge of electricity between a rain cloud and the earth. The electric discharge is seen in the form of a arc between cloud and earth surface.

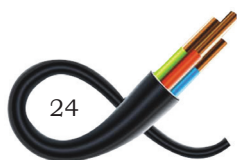
When the electrical potential between two clouds, or a cloud and the earth reaches a sufficiently high value the air becomes ionised along a narrow path and results in lightning flash.

The possibility of lightning is more on tall trees and buildings rather than the ground. Buildings are protected from lightning by metallic lightning rods. These lightning rods are known as lightning arresters. This lightning arrester is fitted at the highest part of the roof and it is extended to the ground through a conductor. The conductor has a pointed edge on one side and the other side is connected to a long thick copper strip which runs down the building. The lower end of the strip is properly connected to the earth. When lightning strikes on the rod the current flows down through the copper strip. These rods provide a low-resistance path for the lightning discharge and prevent it from travelling through the structure of a building itself.

Lightning Arrester

The principle of the lightning arrester was first discovered by Benjamin Franklin in 1749, who in the subsequent years developed his invention for household application.

Lightning arresters (Fig.1.28) are devices which prevent damage of apparatus due to high lightning voltages. The lightning arrester provides a low resistance path to ground for the current from a lightning strike.



When a high voltage or greater than normal line voltage exists in the circuit, the lightning arrester immediately provides a path to earth and thus limits and drains off the excess voltage.

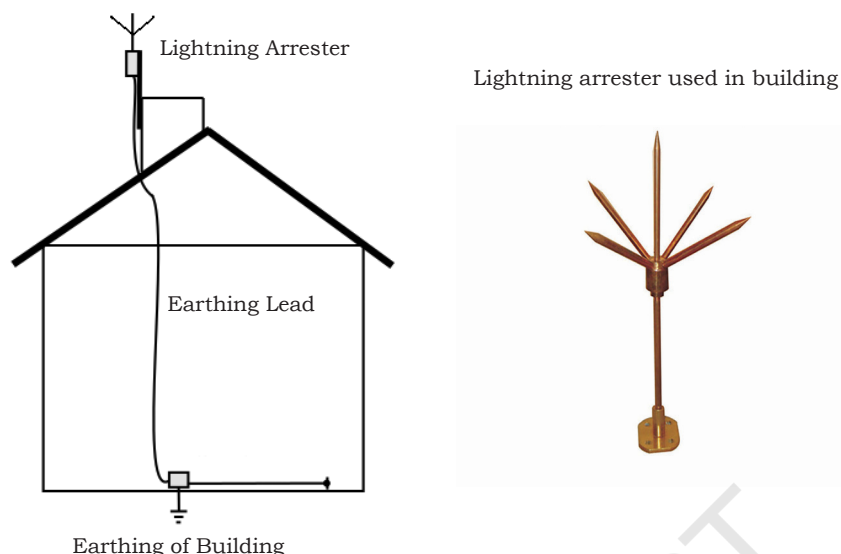


Fig. 1.28 Lightning arresters

Working of Lightning Arrester

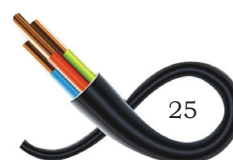
A lightning arrester

1. does not absorb any charge caused by lightning.
2. diverts the charge towards the ground.
3. limits the voltage produced by atmospheric lightning.
4. works at the time of lightning because lightning produces very high voltages.
5. provides protection against lightning surges during rainy session.

Pipe Earthing

This type of earthing is used widely in industries and house wiring system. In this system of earthing, a GI pipe of 30 mm diameter and 2.5 m length is buried vertically into the ground to work as an earth electrode, but the depth depends upon the soil conditions (there are no hard and fast rules for this). The earth electrodes are connected to the top section of the pipe with a nut and bolt. The pit area around the GI pipe is filled with

ELECTRICITY



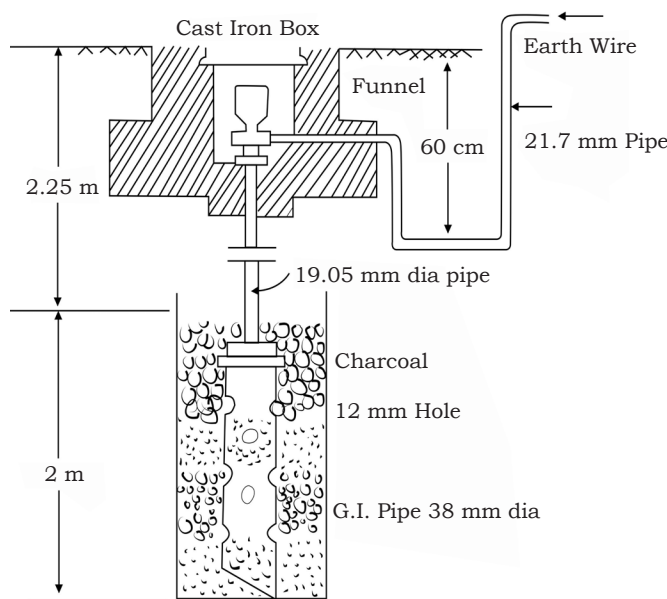


Fig. 1.29 Pipe earthing

an alternate layer of salt and charcoal for reducing the earth's resistance. It can take heavy leakage current for the same electrode size in comparison to plate earthing. Water is filled through pipe to maintain the resistance of earth electrode. Pipe earthing (Fig. 1.29) is the best form of earthing and it is also a cheap method of earthing.

Earthing pipes are also known as earthing electrode pipes, these can be used in houses, office as well as power stations. Earthing pipes are used in electrical installation, transmission line and other installation. Copper pipe is generally used in an earthing system. The pipe size depends upon the current to be carried and on

the soil type. Pipe earthing is reliable, durable, easy to handle and highly secure. Connectivity of the pipe earthing is up to the chamber or earth terminal. The connection of earth wire from machine to Galvanised Iron (GI) pipe, being above the ground level makes it easy to check for any discontinuity.

Pipe earthing gives us the freedom to put 23 buckets of water through the funnel, which helps in achieving effective earthing. It is one of the most widely used method of earthing.

Plate Earthing

In this type of earthing, a plate of copper or GI, is buried into the ground at a depth of greater than 3 m (Fig. 1.30).

Earthing plate is filled with alternate layers of salt and coke not less than 46 cm (1.5 feet) so as to provide lesser resistance due to absorption of moisture. The earth conductor is properly bolted to an earth plate with the help of nut and bolt and washer made of copper, in

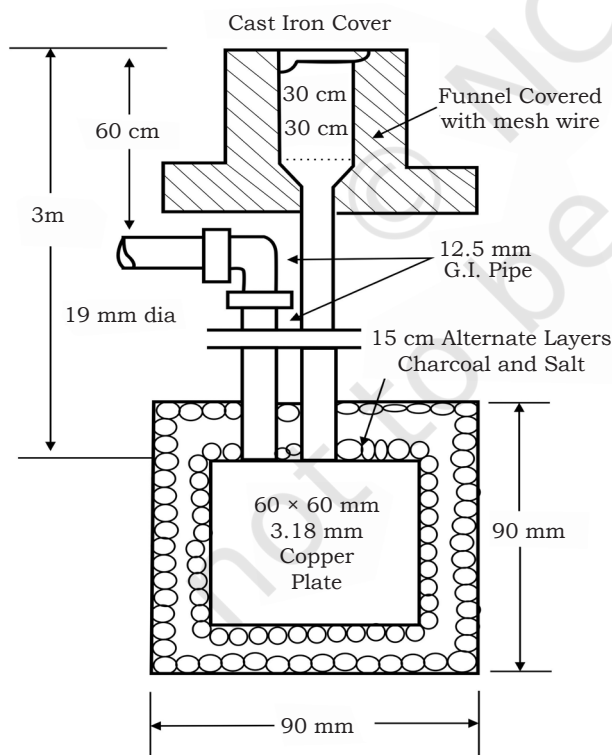
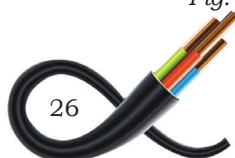


Fig. 1.30 Plate earthing



case of copper plate earthing and of G.I., in case of G.I., plate earthing (Fig. 1.30).

For G.I., the earthing plate size should be $600 \text{ mm} \times 600 \text{ mm} \times 8.30 \text{ mm}$ and for copper earthing the plate size should be $600 \text{ mm} \times 600 \text{ mm} \times 3.15 \text{ mm}$ and the pit size made for maintenance should be $30 \text{ cm} \times 30 \text{ cm}$ so as to provide ease of accessibility of maintenance of these earthing pits and for testing of earthing pits.

Advantages of Earthing

One of the major objectives of earthing is to ensure safety of persons during leakage fault conditions. Earthing creates the path of least resistance from machine to the earth so that the fault current dissipates quickly. It allows the lightning electrical energy to be safely dissipated thereby minimising the danger caused by the lightning. Earthing is the key to safety, i.e., protection of personnel, equipment, wiring, machines and instruments (Fig. 1.31). Another advantage of earthing is in communication tower where it is used to reduce electromagnetic interference.

Both type of earthing processes can be used. But plate earthing is preferred in small buildings and pipe earthing is used for multistorey buildings as well as electrical sub-station. All metallic parts of electric machines must be earthed for safety of equipment.

Earth Resistance

1. Earth resistance depends on the following factors:
 - (a) Type of earth soil
 - (b) Temperature of earth
 - (c) Humidity on earth
 - (d) Minerals on earth
 - (e) Length of electrode
 - (f) Distance between two electrodes
 - (g) Number of electrodes
2. Maximum earth resistance allowed is as follows:
 - (a) Major power station—0.5 ohm
 - (b) Major sub-stations—1.0 ohm
 - (c) Minor sub-station—2 ohm
 - (d) Neutral bushing—0.2 ohm
 - (e) Service connection—4 ohm

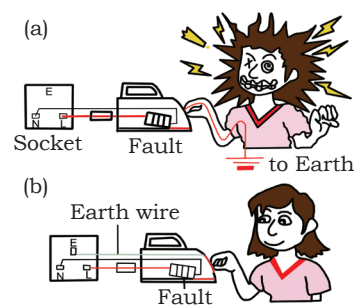
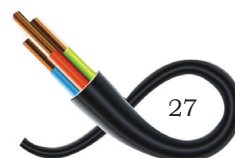


Fig. 1.31 Proper earthing



- (f) L.T. Lightning arrestor—4 ohm
- (g) L.T. Pole—5 ohm
- (h) H.T. Pole—10 ohm
- (i) Tower—20–30 ohm

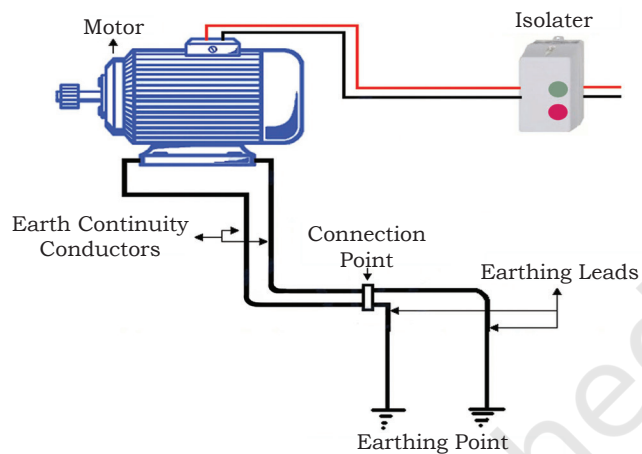


Fig. 1.32 Earthing to the electrical motor

Earth Tester and Resistance

Use of earth tester

Earth tester is used for measuring earth's resistance. If earth's resistance is high, certain processes need to be adopted for controlling it.

Working of earth tester

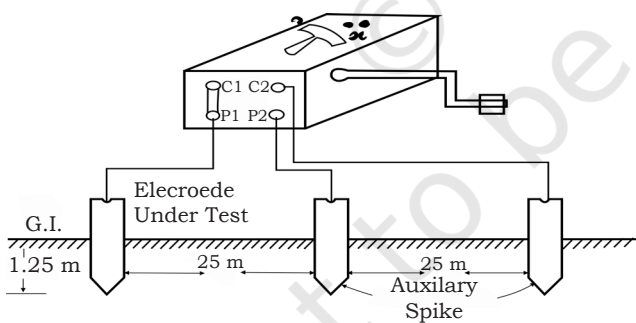


Fig. 1.33 Measurement of Earthing Resistance—Three-Point Method

Earth tester consists of a hand-operated D.C. generator, 4 spikes and a connecting wire. These spikes are connected through wire to terminals of the earth tester. Spikes are inserted in the ground to check the earth's resistance. Current is fed to the spikes through the D.C. generator. The D.C. is converted into A.C. by the converter and the A.C. received from the spike is again converted to D.C.

with the help of a rectifier. While moving towards the generator, the A.C. is fed to the spike driven in the earth as there should be no electrolytic effect.



Three-point method

In this method, earth tester terminals C1 and P1 are joined to each other and connected to the earth electrode (pipe) under test. Terminals P2 and C2 are connected to the two separate spikes driven in earth (Fig. 1.33). These two spikes are kept in the same line at a distance of 25 metres and 50 metres each due to which, there will not be mutual interference in the field of individual spikes. If we rotate the generator handle at a specific speed, we will directly get the earth's resistance on scale. This method of testing is known as the three-point method.

Note: Spike length in the earth should not be more than 1/20th distance between two spikes.

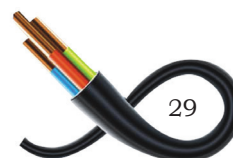
Four-point method

In this method, four spikes are driven in the earth in the same line at an equal distance. Outer two spikes are connected to C1 and C2 terminals of earth tester. Similarly, inner two spikes are connected to P1 and P2 terminals. Now, if the generator handle is rotated at a specific speed, earth's resistance value of that place can be obtained.

In this method, error due to polarisation effect is eliminated and earth tester can be operated directly on A.C.

If earth's resistance is higher, the following treatments can be done to minimise the resistance.

- (a) Oxidation on joints should be removed and joints should be tightened.
- (b) Sufficient water should be poured into earth's electrode.
- (c) Earth electrode of bigger size as far as possible should be used.
- (d) Electrodes should be connected in parallel.
- (e) Earth pit of more depth and width-breadth should be made.



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Check Your Progress

A. Fill in the Blanks

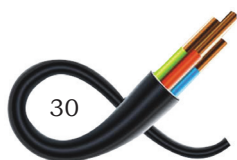
1. The metallic connection between electrical machines and devices with the earth plate, through a thick wire is known as _____.
2. _____ earthing is a cheap and best form of earthing.
3. The resistance between earth electrode and earth in Ohms is called _____.
4. Earthing saves human lives from _____.
5. The unit of earth resistance is _____.

B. Match the Columns

- | | |
|------------------------|--------------|
| 1. Major sub-station | A. 20–30 ohm |
| 2. Major power station | B. 2 ohm |
| 3. Minor sub-station | C. 0.5 ohm |
| 4. Tower | D. 1 ohm |

C. Multiple Choice Questions

1. Earth resistance value of house wiring is _____.
(a) 5 ohm
(b) 2 ohm
(c) 1 ohm
(d) 8 ohm
2. The most commonly used type of earthing is _____.
(a) plate earthing
(b) pipe earthing
(c) rod earthing
(d) strip earthing
3. Ideal value for earth's resistance in ohm is _____.
(a) 1
(b) 2
(c) 3
(d) 0
4. For maintaining moisture around the earthing we use _____.
(a) salt and charcoal
(b) sugar
(c) oil
(d) None of the above
5. Every metallic electrical pole must be _____.
(a) grounded
(b) earthed
(c) phase
(d) neutral



D. Short Answer Questions

1. What do you understand by electrical earthing? Why is it done?
2. Which electrical points should be earthed?
3. Write down the earth's resistance of different electrical installations.
4. What are the different types of earthing?
5. Draw a simple diagram of pipe earthing.

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